

Brief report after SnowMass CPM Muon Collider Lol

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SnowMass Community Planning Meeting

<https://indico.fnal.gov/event/44870/>

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Contributed Papers (deadline July 31, 2021)

<https://snowmass21.org/submissions/>

Some comments – Physics Potential

Michael Peskin

In principle, lepton colliders in the 500-3000 GeV energy regime could be either e^+e^- or $\mu^+\mu^-$ colliders.

In general, I will quote projected accuracies of measurements from studies for the e^+e^- colliders ILC and CLIC. These are based on full detector simulation including all SM backgrounds.

For $\mu^+\mu^-$ colliders, there are no studies at this level. It is known that machine backgrounds are severe, due to muons decaying into the detector from upstream. Optimistically, one might expect that the same performance as at e^+e^- colliders can be achieved using detectors of the future (e.g. timing calorimeters). However, this ought to be demonstrated, not assumed.

More optimistic

Patrick Meade

Who knows what the future holds?

AKA Why now?

- We don't know if ILC , FCC, CEPC/SPPC will go forwards
- It's hard to imagine more than one mega project gets a greenlight soon...
- **IF** a high energy lepton collider *could* be an all-in-one collider we need to demonstrate it **now** as an alternative
 - There is work to be done on the Accelerator side - muons maybe closer? But we need something concrete and $\gtrsim \mathcal{O}(10)$ TeV!
 - New detector technologies to deal with backgrounds, nuts and bolts estimates to show whether precision means precision
 - R&D for this can be good for all, timing, trigger, radiation mitigation for detector, magnets etc. so investing this effort isn't taking away from something else

How to organize work at best?

extras

Physics potential and theory related

SNOWMASS21-EF0_EF0-TF0_TF0-AF0_AF0-244

Beyond the Standard Model with High-Energy Lepton Colliders

Exploring the coverage of motivated scenarios for physics beyond the Standard Model and highlighting unique opportunities afforded by energetic lepton beams, we aim to identify energy and luminosity goals that would position such a collider as a natural successor to the LHC and proposed electron-positron Higgs factories.

In the interest of letting the physics case guide the accelerator parameters, we propose to study the physics potential of muon colliders across a wide range of center-of-mass energies, from $\sqrt{s} = 1 - 100$ TeV. While the upper end of this scale lies on the extreme edge of existing proposals, it may well be motivated by the most compelling physics case. Our study will cover a range of compelling scenarios related to naturalness, dark matter, and electroweak symmetry breaking, as well as bottom-up simplified models spanning the relevant signature space.

The ultimate goal is to provide a comprehensive view of the physics case for a high-energy lepton collider, engaging the US HEP community and laying down a marker for accelerator design.

Physics - Theory

SNOWMASS21-TF7_TF0-EF4_EF0-026

EW effects in very high-energy phenomena

ISR and FSR in multi-TeV lepton (electron and muon) collider and at 100+ TeV pp collider

Machine parameters

SNOWMASS21-AF4_AF0-EF0_EF0-103

International Muon Collider Collaboration

Motivation – Scope – Plan – Initial workplan

Identification and conceptual design of the key demonstration facilities and components will define the R&D path for the CDR phase and allow to assess its cost and timeline.

The construction of models for key hardware might be required during this phase.

Muon Acceleration for a $\sqrt{s} = 10$ TeV $\mu^+\mu^-$ Collider

Machine Issues

SNOWMASS21-AF3_AF7-035

Solving Critical Problems of the Muon Collider Higgs Factory: Optics, Magnets and their Protection, and Detector Backgrounds - 125 GeV c.o.m. energy

detailed study of a low- energy medium-luminosity Muon Collider Higgs Factory (MCHF) collider ring (CR) which includes the arc and the interaction region (IR)

- (1) a versatile CR design that permits two operation modes (high luminosity or low energy spread),
- (2) large-aperture high-field superconducting (SC) magnets and their protection against muon decay products, and
- (3) reduction of background particle fluxes in the MCHF detector to the tolerable levels.

Machine Technologies

SNOWMASS21-AF7_AF4_R._LI_VOTI_and_G._CESARINI-137

Studies of target materials and layout for a low emittance muon source (LEMMA)

Be and C composites/structures

A theoretical model to deal with such a scheme has been developed, and the simulations tools have been put in place

The model can be successfully applied to other target materials and layout, as for example the MAP muon source

Future R&D: experimental and theoretical activities

Machine Detector Interface

Detector and reconstruction tools

Luminosity Measurement

SNOWMASS21-TF7_TF0-EF4_EF0-AF4_AFO-046

At a muon collider, given the peculiar structure of the MDI, a similar method can be used to measure the luminosity. We propose to study the feasibility of the reconstruction of $\mu^+\mu^- \rightarrow \mu^+\mu^-$ events at large angle with respect to the beam line to get $L = \frac{N}{\sigma_{\mu^+\mu^-}}$. Here N is the number of di-muon events, and $\sigma_{\mu^+\mu^-}$ is the theoretical muon Bhabha cross section. It is important to evaluate the number of reconstructable events at large angle and the precision with which the theoretical cross section has to be known. The studies can be organized as follow:

- Produce a sample of $\mu^+\mu^- \rightarrow \mu^+\mu^-$ events at $\sqrt{s} = 1.5\text{TeV}$, $\sqrt{s} = 3.0\text{ TeV}$ and $\sqrt{s} = 10\text{ TeV}$ by using a tree-level Monte Carlo generator and study the reconstruction efficiency at large angle by using the full detector simulation and identify additional kinematical requirements that can help the obtain a more precise theoretical prediction.
- Perform the same studies with Mu-BabaYaga event generator [5].
- Evaluate the theoretical precision on the Bhabha cross section.
- Determine the expected precision on the luminosity.